A Novel Method of Delivering Small Payloads from a Planetary Orbiter to the Surface

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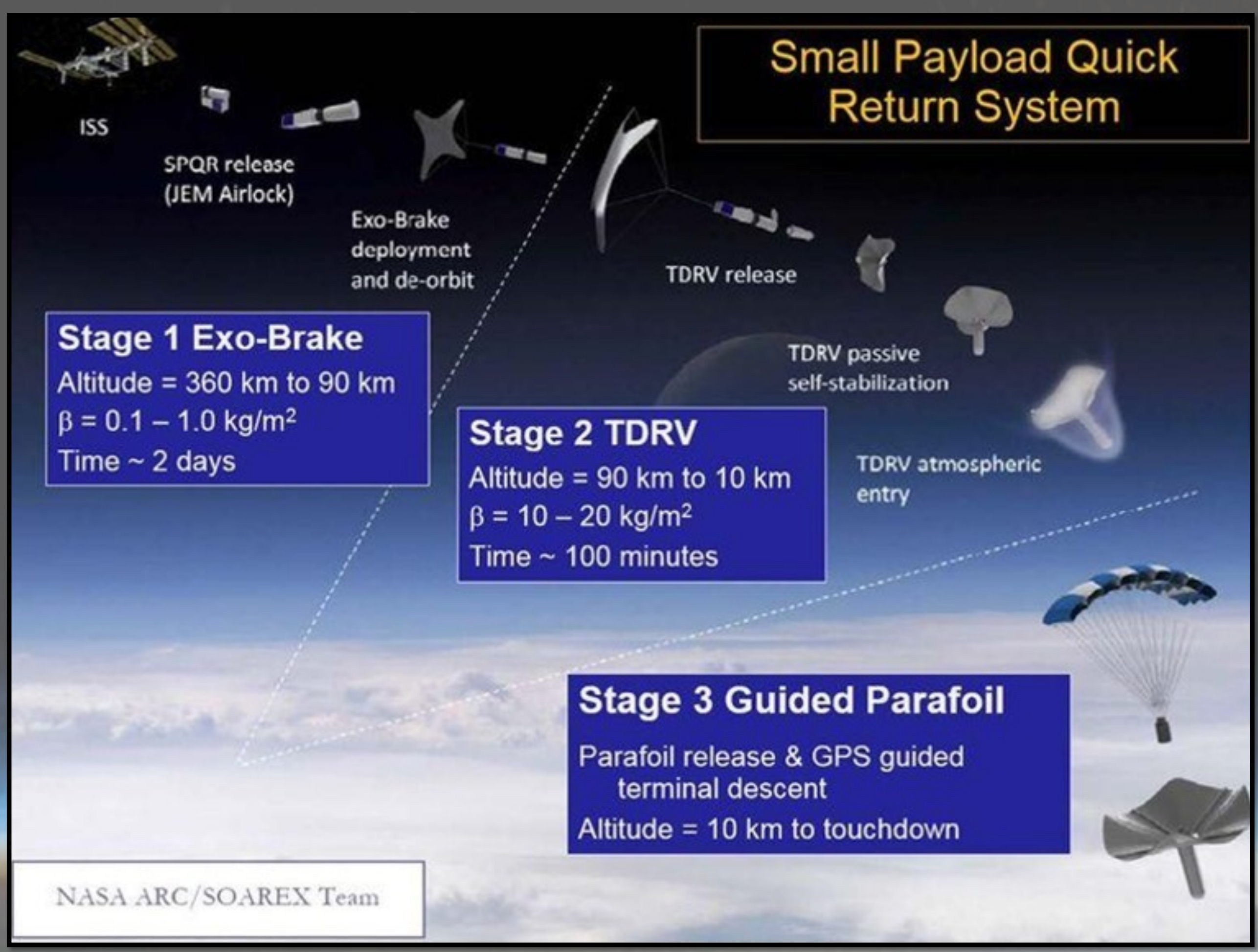
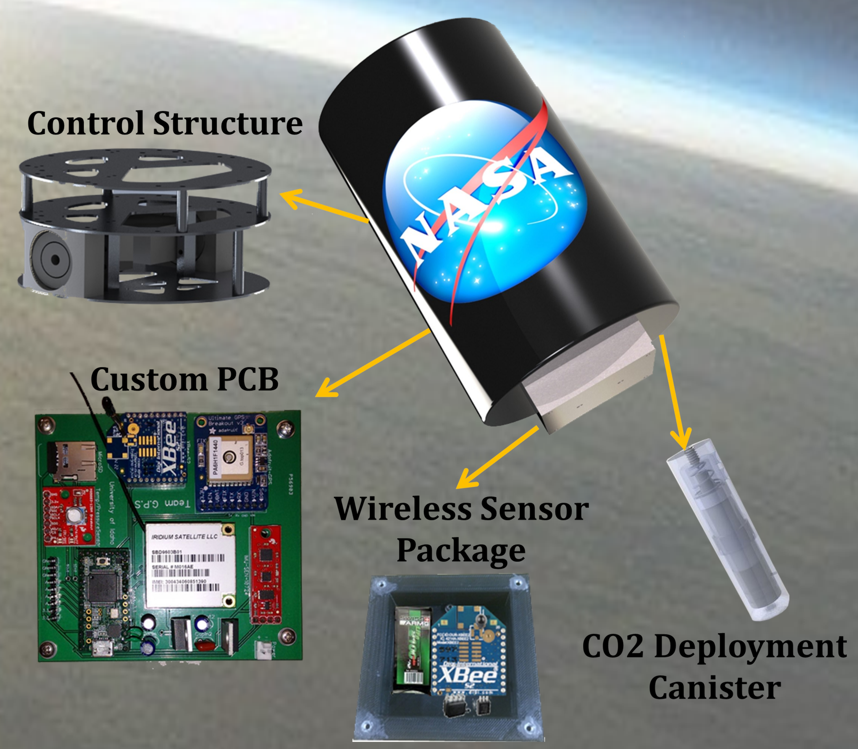


Abstract: Returning small payloads from planetary orbit to the surface is necessary for a range of scientific investigations on Earth and possibly other major planets. Traditionally this has required powered flight, which is often expensive and long-delayed. A Capstone Senior Design Team at the University of Idaho, in collaboration with researchers from NASA Ames Research Center and NASA Jet Propulsion Laboratory, has been developing a system of quickly, safely, and inexpensively returning small payloads from the International Space Station to a specified location on Earth via a Small Payload Quick Return System (SPQR) comprising three independent stages. The first stage utilizes an exobrake to deorbit the payload, and the second stage is a Tube-Deployable Release Vehicle designed to transition from space to atmosphere. The Senior Design Team has focused on the third stage of payload return, involving a guided parafoil, complete with various electronic subsystems, to steer the payload to a pre-specified latitude and longitude on Earth from an elevation of approximately 50,000 to 100,000 feet. This stage includes an array of wireless sensors in combination with a data logger to manage data acquisition, storage, and communication to operators on the ground, and a graphical user interface (GUI) was developed to display the data. It also includes a parafoil deployment and inflation system to combat the low-density atmosphere that the payload will experience at these high elevations, and a winch-based flight control system – in tandem with a Global Positioning System (GPS) – to safely guide the payload to a specified location. Upon design completion, the system was tested on a high-altitude balloon. Data was acquired, stored, and transmitted during the entire ascent and descent of the payload for later analysis.

Benefits of a Guided Parafoil System

- Using a passive flight system to return a payload is significantly less expensive than powered flight systems, such as a rocket.
- A guided parafoil system requires less space and mass than other reentry vehicles, such as the SpaceX Dragon capsule. It is also less prone to catastrophic failure, and therefore—in the unlikely case of a failure—the system is less likely to damage the surrounding equipment.
- The guided parafoil system is much more simple than other flight systems, and therefore easier to repair or modify to fit specific needs.



Results

- During ground testing the system successfully controlled two winches to steer the parafoil. The system polled data, stored it on the microSD card, and transmitted it via the Iridium satellite network. The GUI parsed the data and displayed it on a web server in near real time.
- During flight testing a third-party error caused the system to be cut down at 300 meters elevation. Due to the low altitude the flight control system had not been automatically activated to avoid line tangling. All other enabled subsystems, including the GUI, worked as expected.

Wireless Sensor Scheme

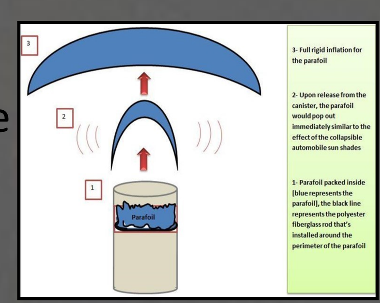
- XBee Series 2 wireless radios to communicate sensor data at up to 120 meters away from the main payload.
- Each wireless package includes an analog temperature and pressure sensor.
- Code is written to interface directly with the XBee via Serial.
- 3D-printed casing protects the XBee, sensors, and battery from temperature and impact.
- Modules are designed to be “plug and play.”

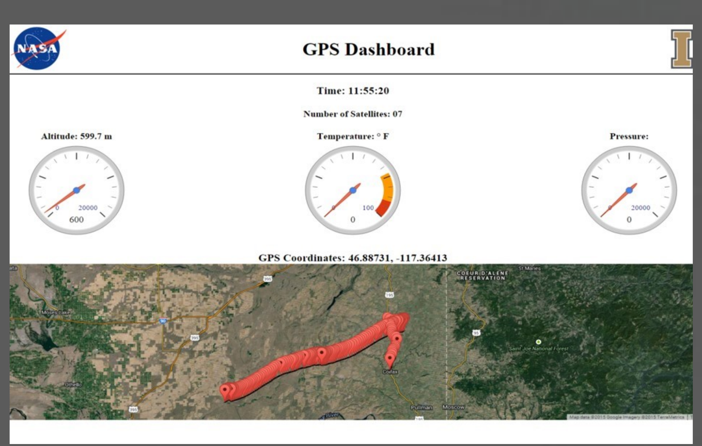
Control and Data Logging

- Teensy 3.1 (Arduino IDE) microcontroller at 96 MHz.
- Adafruit GPS with Serial interface.
- XBee Series 2 wireless radio for sensor communication.
- Iridium 9603 SBD modem for real-time communication.
- Digital and analog sensor array.
- microSD card for local data storage.
- Custom printed circuit board (PCB).
- Two winches for flight control.

Parafoil Deployment and Inflation

- Uses easily-attainable CO_2 Cartridges for initial deployment.
- Parafoil tethered to payload with 50-lbf (222.4 N) fishing line.
- Fiberglass rods are sewn in to the perimeter of the parafoil to enable it to “pop open” similar to an automobile sun shade.
- 90-degree elbow connectors in parafoil corners maintain integrity during inflation and flight.
- 50-lbf (222.4 N) Teflon-coated braided line will be used to reduce line tangling.





Graphical User Interface

- The GUI, pictured to the left, allows operators on the ground to monitor the location, altitude, temperature, and pressure in near real time while the payload is in flight.
- The payload transmits status updates via the Iridium satellite network. Iridium sends the information as comma –separated values to a Gmail account. The GUI accesses the email, parses the data, and displays it graphically for easy interpretation.
- The GUI indicates the strength of the GPS signal and plots the path of the payload during ascent and descent for simplified payload tracking and recovery.

System Testing and Future Work

- The Control and Data Logging board was tested in a vacuum chamber to simulate the low-pressure atmosphere at typical flight altitudes.
- Many components were tested in a cold chamber to simulate low temperatures at high altitudes.
- The parafoil deployment system was ground-tested, but not flight-tested.
- The system was flown on a high-altitude balloon and was mostly successful.
- Future work: Optimize flight algorithm; Test parafoil deployment system in high altitude; Switch from through-hole to surface-mount components.

References: [1] Benton, Joshua E. "Miniaturization, Integration, Flight Testing, and Performance Analysis of a Scalable Autonomous GPS-Guided Parafoil System for Targeted Payload Return." Thesis. San Jose State University, 2012. Print. [2] Slegers, N.J. and Yakimenko, O.A., “Optimal Control for Terminal Guidance of Autonomous Parafoils.” 20th AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar, Seattle, Washington, 4 - 7 May 2009. [3] Yakimenko, O. A., Slegers, N. J., and Tiaden, R.A. “Development and Testing of the Miniature Aerial Delivery System Snowflake.” 20th AIAA Aerodynamic Decelerator Systems Technology Conference and Seminar, Seattle, Washington, 4 - 7 May 2009.

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